Simulating restoration of the Iraqi Mesopotamian marshland

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Introduction

The Tigris and Euphrates Rivers arise in the mountains of southern Turkey, and flow southeastwards into Iraq. The watersheds of both the Euphrates and the Tigris are predominantly in the countries of Turkey, Syria, and Iraq (Figure 1). These rivers are the main sources of water in Iraq and their confluence in southern Iraq forms the Mesopotamian Wetlands.

The Mesopotamian marshlands are the largest wetland ecosystem in the Middle East, have been the home to the Marsh Arabs for 5000 years, and support a rich biodiversity (UNEP, 2001). Since 1970, the wetlands have been dramatically changed. The wetlands once covered between 15,000 and 20,000 km^2 but covered less than 760 km^2 by 2000 (Figure 2). There was an additional 30% decline from 2000-2002. If this trend were to continue, the wetlands would have disappeared in 5 years. More recently, there has been an international effort to restore the Mesopotamian Marshlands (Richardson et al., 2005). This presentation is of a simple simulation model that was developed to describe the ecology, hydrology, and water quality of a typical marsh in the region as it is subjected to variations in hydrology of drainage and reflooding.

The model

A preliminary, easy-to-use STELLA simulation model was developed for the Mesopotamian Marshlands of Southern Iraq (Figure 3). The model includes simple

Figure 1. The Tigris-Euphrates Drainage Basin (UNEP, 2001)

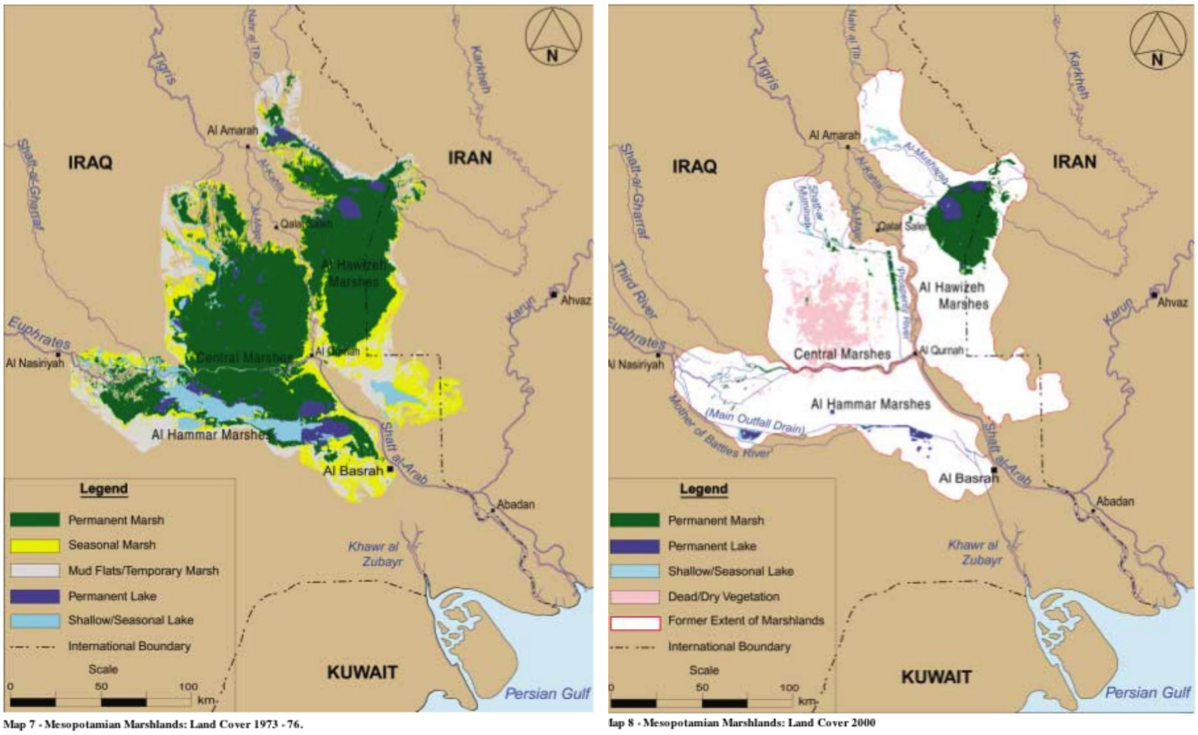

Figure 2. Mesopotamian Marshlands Land Cover: left, 1973-76; right, 2000. (UNEP, 2001)

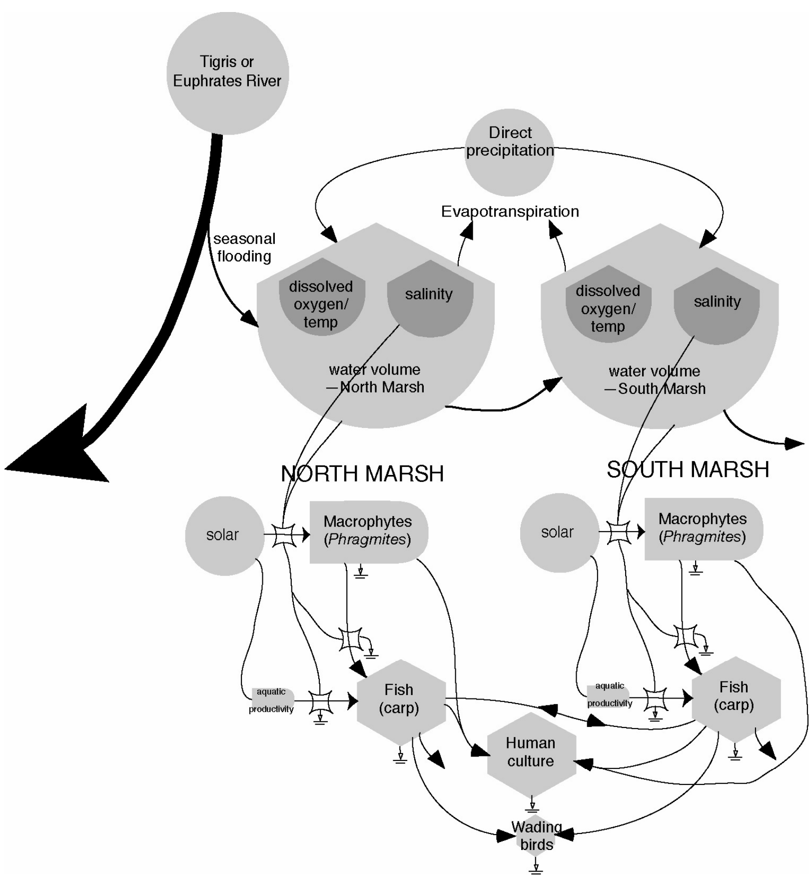

Figure 3. SWAMP II Mesopotamian Marshland conceptual model

algorithms for site hydrology, water salinity, macrophyte (Phragmites) biomass, and fish (generalized as carp) (Figure 4). The model in principle can be applied to any marsh restoration or management issues in the region. The model is designed to give a first-cut estimation of the effects of marshland restoration approaches on functions related to human use of the marshlands. It simulates the ecosystem for a total of 52 weeks (1 year) and can be extrapolated to cover a longer time, e.g. 10-20 years, when more data are available for model calibration.

The model is based on previous models developed at Ohio State University, specifically models developed for wetlands on the Great Lakes (Mitsch and Reeder, 1991), a constructed flow-through wetland in Illinois (Christensen et al., 1994; Wang and Mitsch, 2000), and an aquatic food-chain and hydrology models of a created river-connected wetland in Ohio similar in function to the Mesopotamian Marshlands (Metzker and Mitsch, 1997; Zhang and Mitsch, 2005). These models were referred to as SWAMP (Simulated Wetlands Applied to Management Problems). This current version designed for the Mesopotamian Marshlands is referred to as SWAMP II. The model is written in high-level language STELLA and can be operated by STELLA 8.01 or higher. Figure 4 shows the SWAMP II Mesopotamian Marshland fish submodel in STELLA symbols.

Results

The model has several forcing functions and coefficients that are given default values until site-specific data are determined. The model is also developed to include two wetland basins in series with hydrologic connection directly or indirectly to the Tigris or Euphrates Rivers (Figure 5). Figures 6 shows typical simulation results while Figure 7 shows the interface for setting river conditions in the model.

Model parameters

The important model parameters that can be set include the following:

Forcing functions related to river flow

pre-dam Tigris—flow of Tigris River prior to dam construction in the 1970s. Units are in m^3/week.

post-dam Tigris—flow of Tigris River after dam construction in the 1970s. Units are in m^3/week.

pre-dam Euphrates—flow of Euphrates River prior to dam construction in the 1970s. Units are in m^3/week.

post-dam Euphrates—flow of Tigris River after dam construction in the 1970s. Units are in m^3/week.

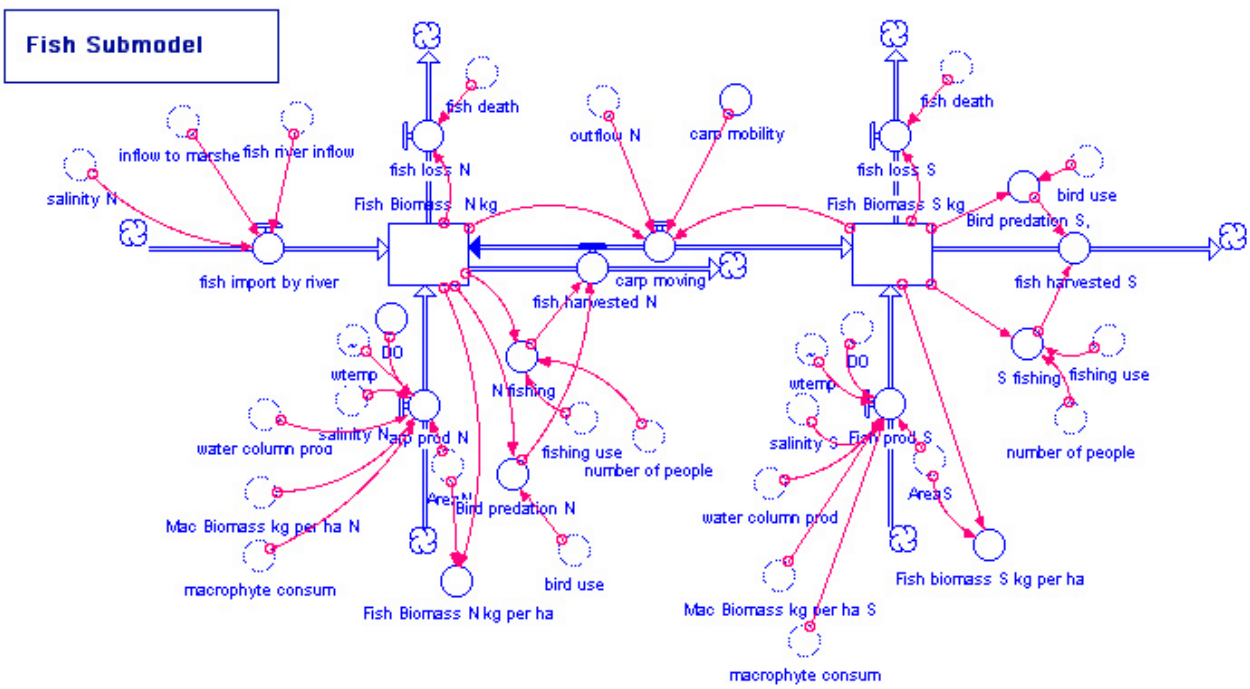

Figure 4. Fish biomass STELLA submodel from SWAMP II model

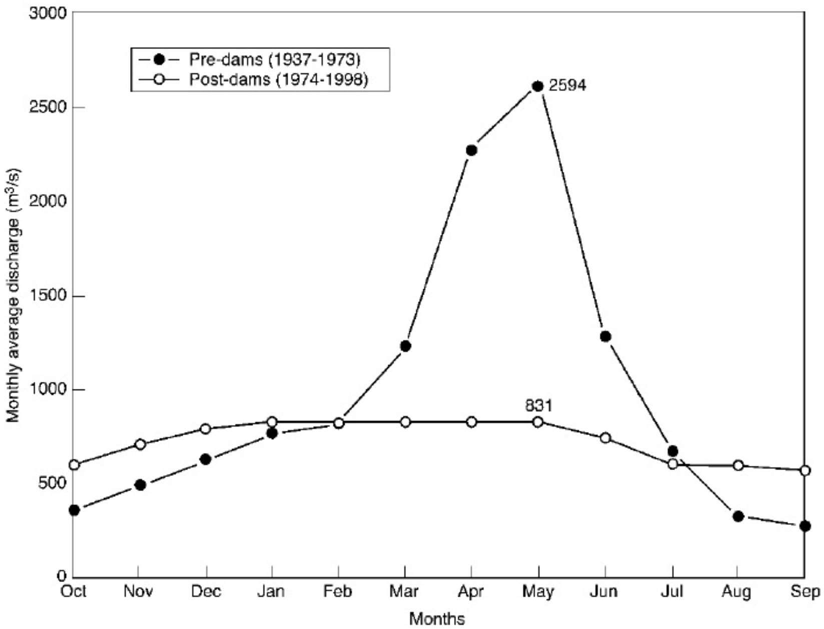

Figure 5. Comparison of the flow regimes for the Euphrates River at Hit-Husabia, Iraq, pre-dams and post dams. Source: UNEP (2001).

Tigris switch; Eu switch— Switches for each river that allow selection of Tigris or Euphrates River as source of water. Value can be 1 or 0 and only one river should be given a 1 for each simulated site.

flooding factor—A measure of the portion of river flow that goes to the marshlands. Scale is 0 (no river water) to 1 (100 % river flow).

Forcing functions related to climate and water quality

airtem—pattern of weekly air temperature for study site in °C.

solar—pattern of weekly solar radiation for study site in kcal m^{-2} wk^{-1}.

precip—pattern of precipitation for study site in m/wk.

ET— pattern of potential evapotranspiration for study site in m/wk.

dissolved oxygen—average dissolved oxygen, mg/L. (eventually this can be developed as a state variable).

Wetland area and population

North marsh area—area of northern marshland, ha

North marsh area—area of southern marshland, ha

number of people—people who are living in the study area and utilize the marshland for food and fiber (default = 3,000 people)

Model parameters

wtemp—wetland water temperature for region, weekly data in °C

salinity factor—macrophyte growth coefficient (0-1) as a function of salinity (ppt)

macrophyte solar eff—solar efficiency, conversion of solar energy to energy of macrophyte productivity, kcal/kcal (default = 0.025)

macrophyte resp—macrophyte respiration coefficient (default = 0.09 wk^{-1})

macrophyte death—macrophyte death/loss coefficient (variable; seasonal = 0 to 1 wk^{-1})

water level factor N; water level factor S—macrophyte growth as a function of water depth for north and south marshlands

fish river inflow—coefficient for fish entry with river flooding (default = 0.05)

fish mobility—relative mobility of fish between marsh basins (default = 1)

fish death—death coefficient for fish (default = 0.04 wk^{-1})

fishing use— coefficient of fishing by human population (default=0.00067 individuals-wk^{-1})

bird use—coefficient for bird harvesting of fish (default = 0.001 wk^{-1})

water column prod—average annual water column productivity (default = 140 g m^{-2} wk^{-1})

macrophyte consum—relative macrophyte consumption by carp (default = 0.01 wk^{-1})

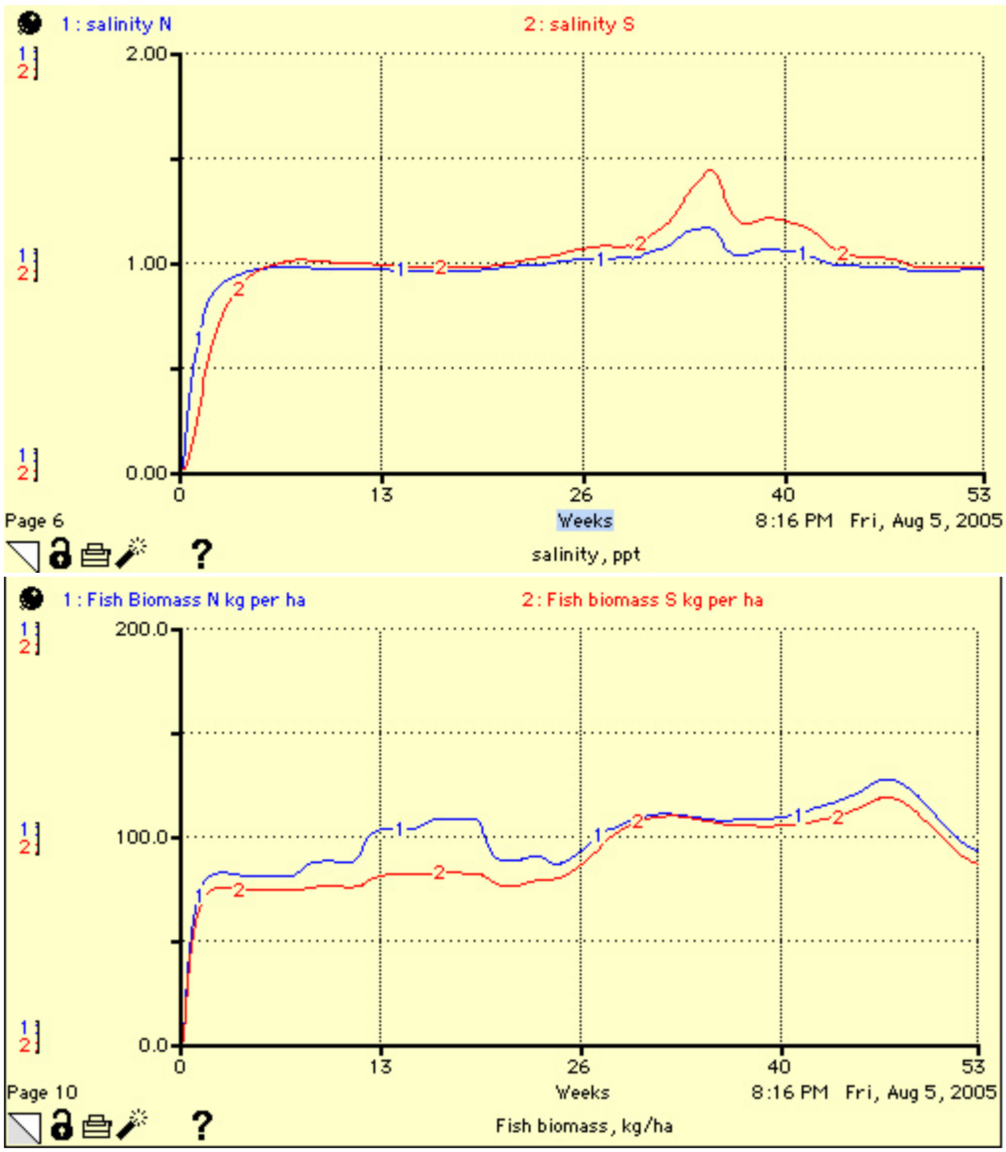

Figure 6. Simulation results of the model for salinity and fish biomass.

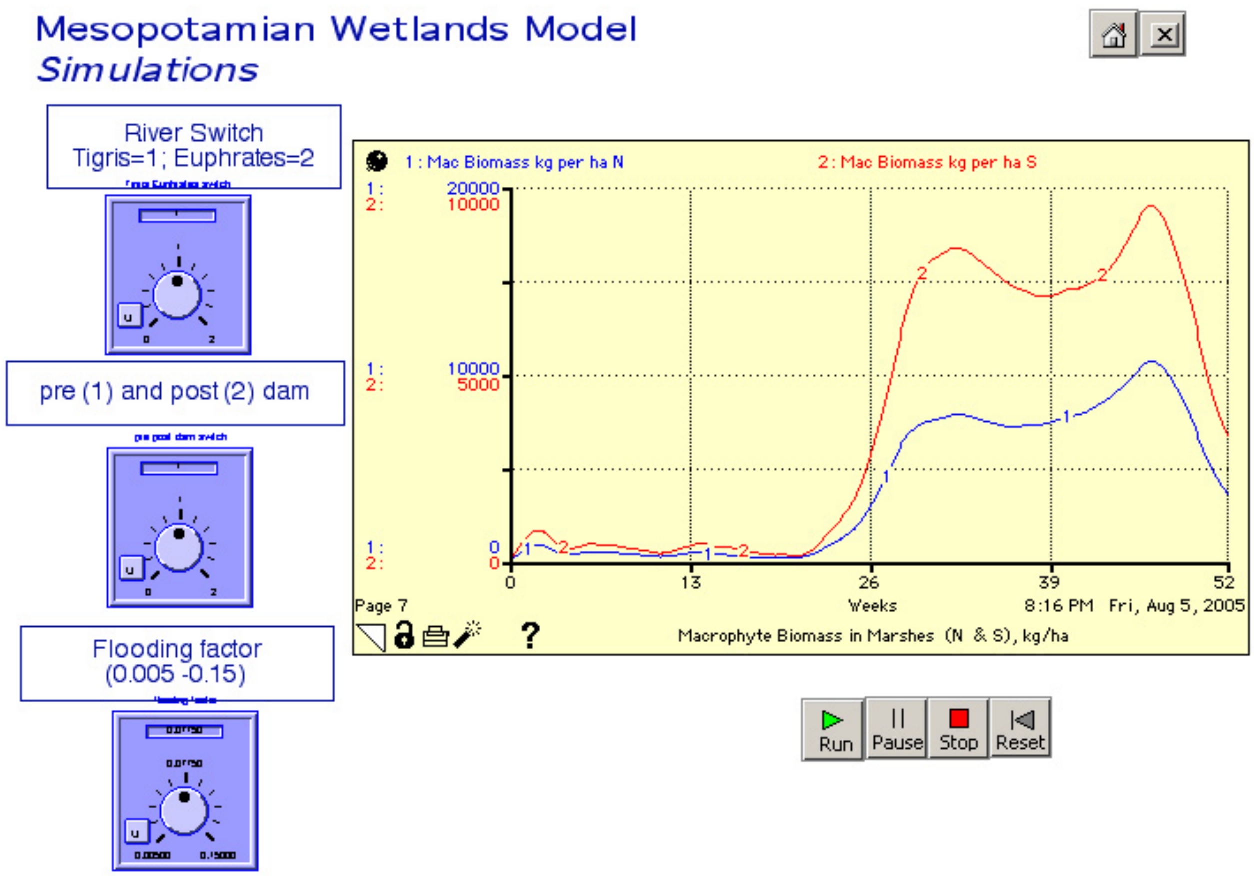

Figure 7. Interface of simulation results with inflow controls.

Acknowledgments

This project was supported by the International Technology Centre of United Nations Environmental Programme, Shiga Prefecture, Japan.

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